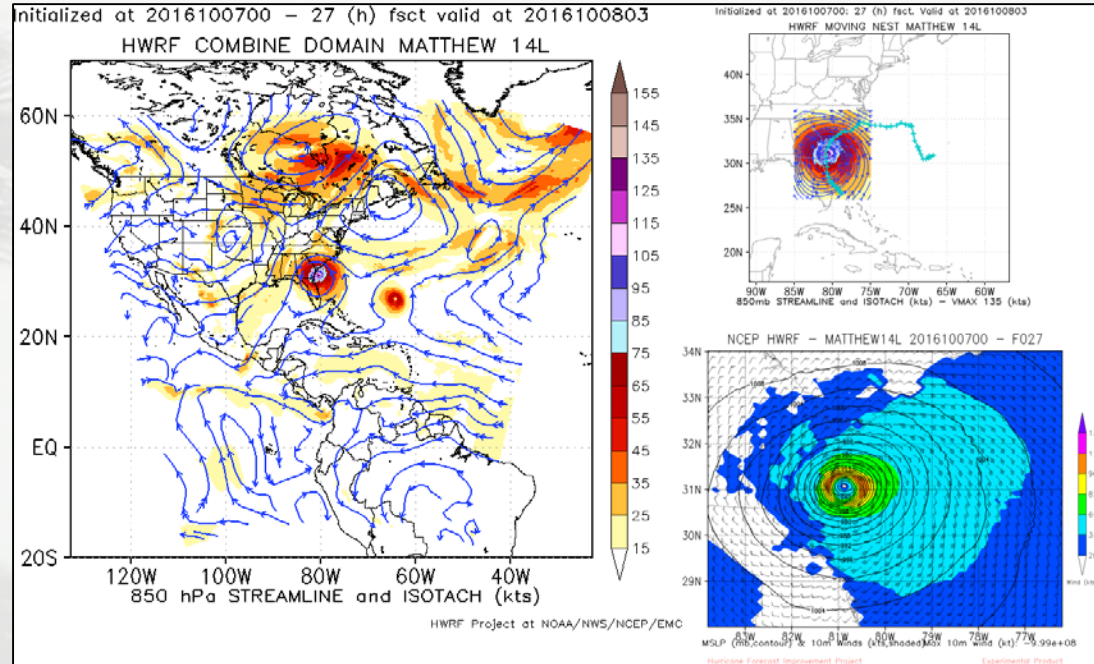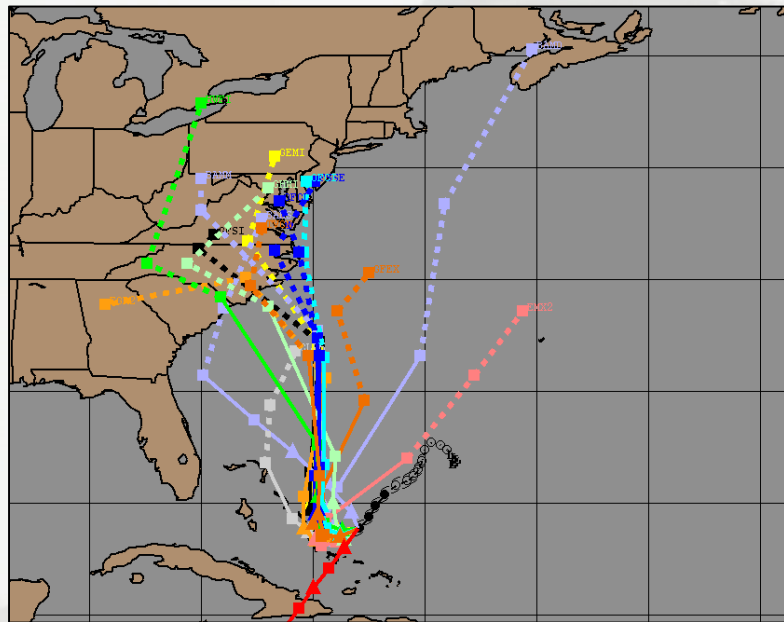# Tropical Cyclone Track
Overview, Challenges, and Forecast Philosophy

Michael J. Brennan

National Hurricane Center
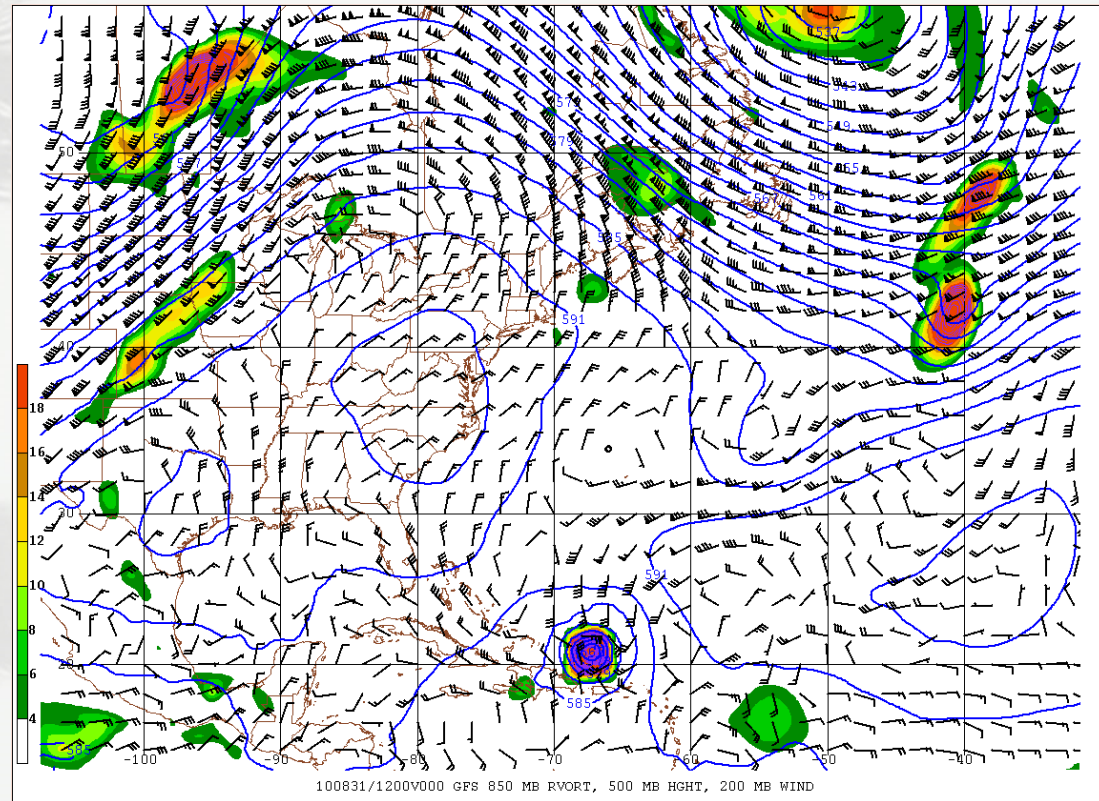
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Tropical Cyclone Track
Overview

- **Track forecasting is a relatively simple problem**
  - "Cork in a stream" analogy

- **Important atmospheric features that control track are relatively large and easy to measure**

100831/1200V000 GFS 850 MB RVORT, 500 MB HGHT, 200 MB WIND

Tropical Cyclone Models
Statistical and Dynamical

- ## **Statistical**

  – Tells you what ***normally occurs*** based on the behavior of previous storms in ***similar situations*** (i.e., storm location, time of year, current motion, intensity, environment)

- ## **Dynamical**

  – Attempt to predict what will happen in this ***specific situation***

Tropical Cyclone Models
Statistical and Dynamical

- **Statistical**

  – Tells you what ***normally occurs*** based on the behavior of previous storms in ***similar situations*** (i.e., storm location, time of year, current motion, intensity, environment)
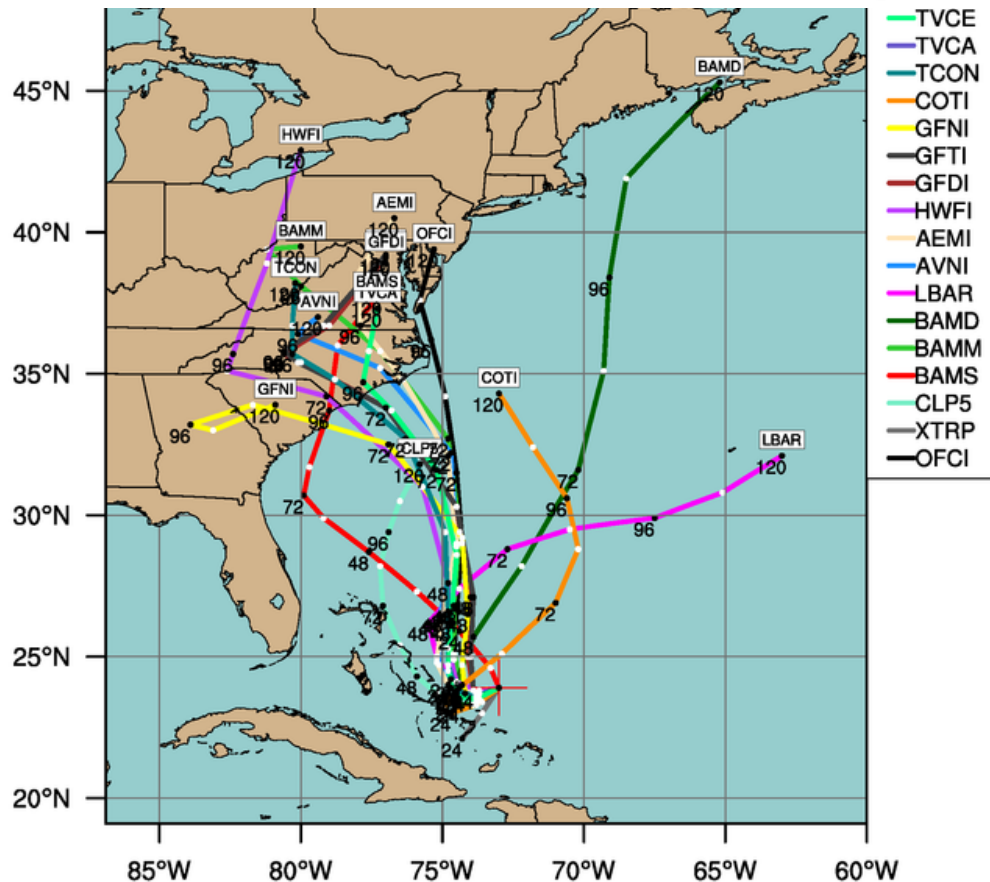
- **Dynamical**

  – Attempt to predict what will happen in this ***specific situation***

Tropical Cyclone Models
Spaghetti Plots
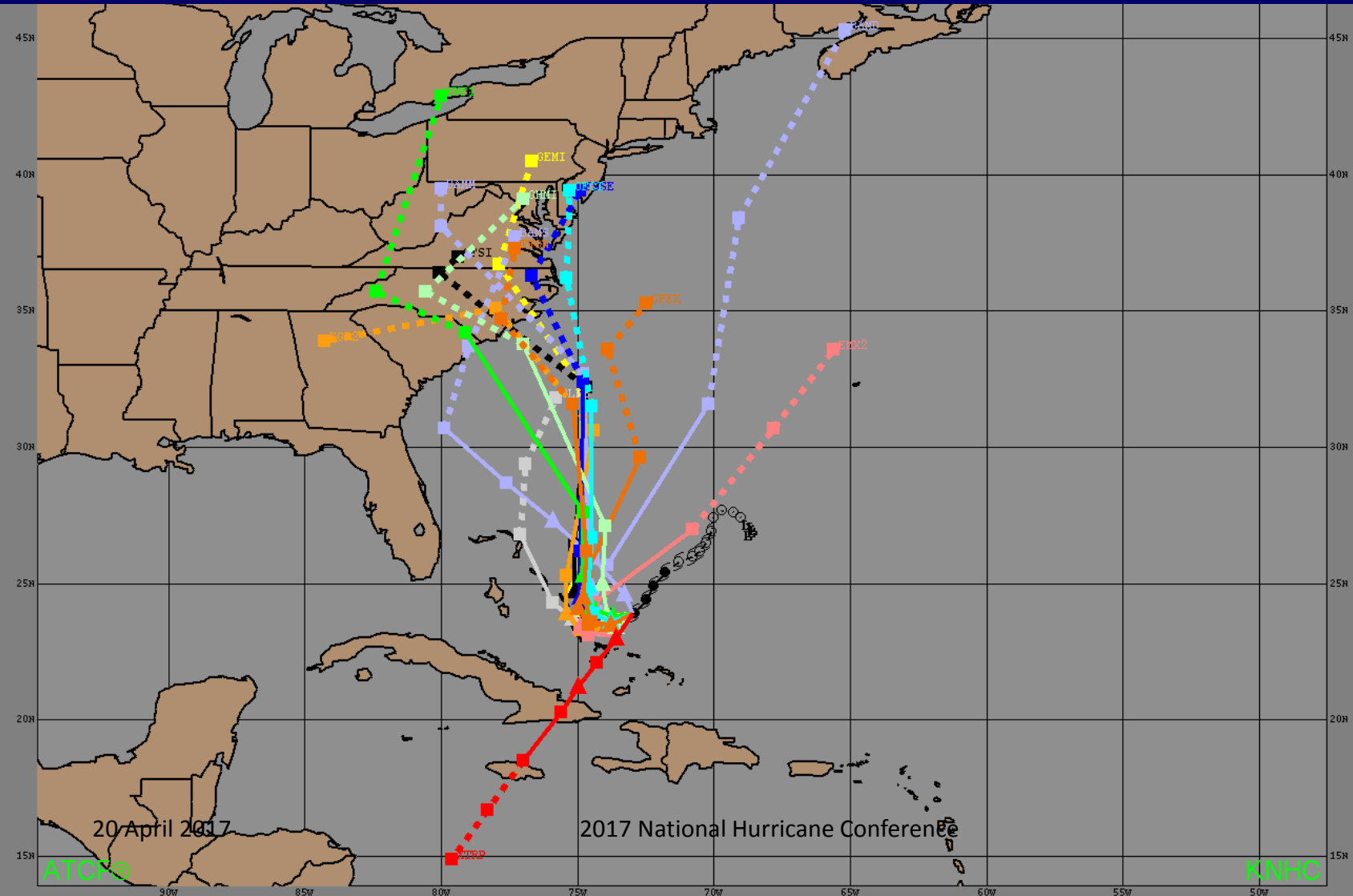

MAJOR HURRICANE JOAQUIN (AL11)

- What does this set of lines represent?
- Do they accurately convey the uncertainty in the track forecast?
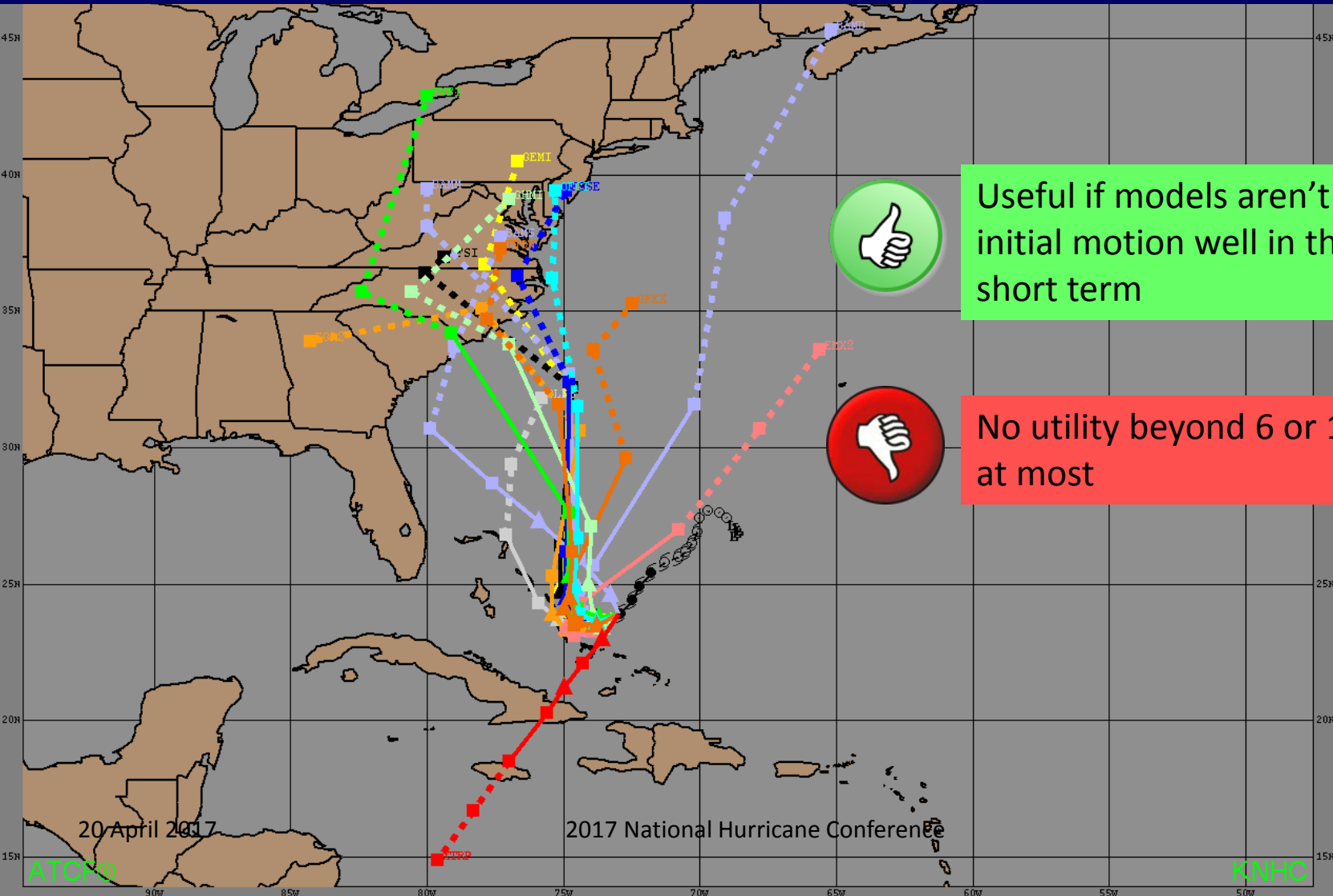- Are they all created equal?
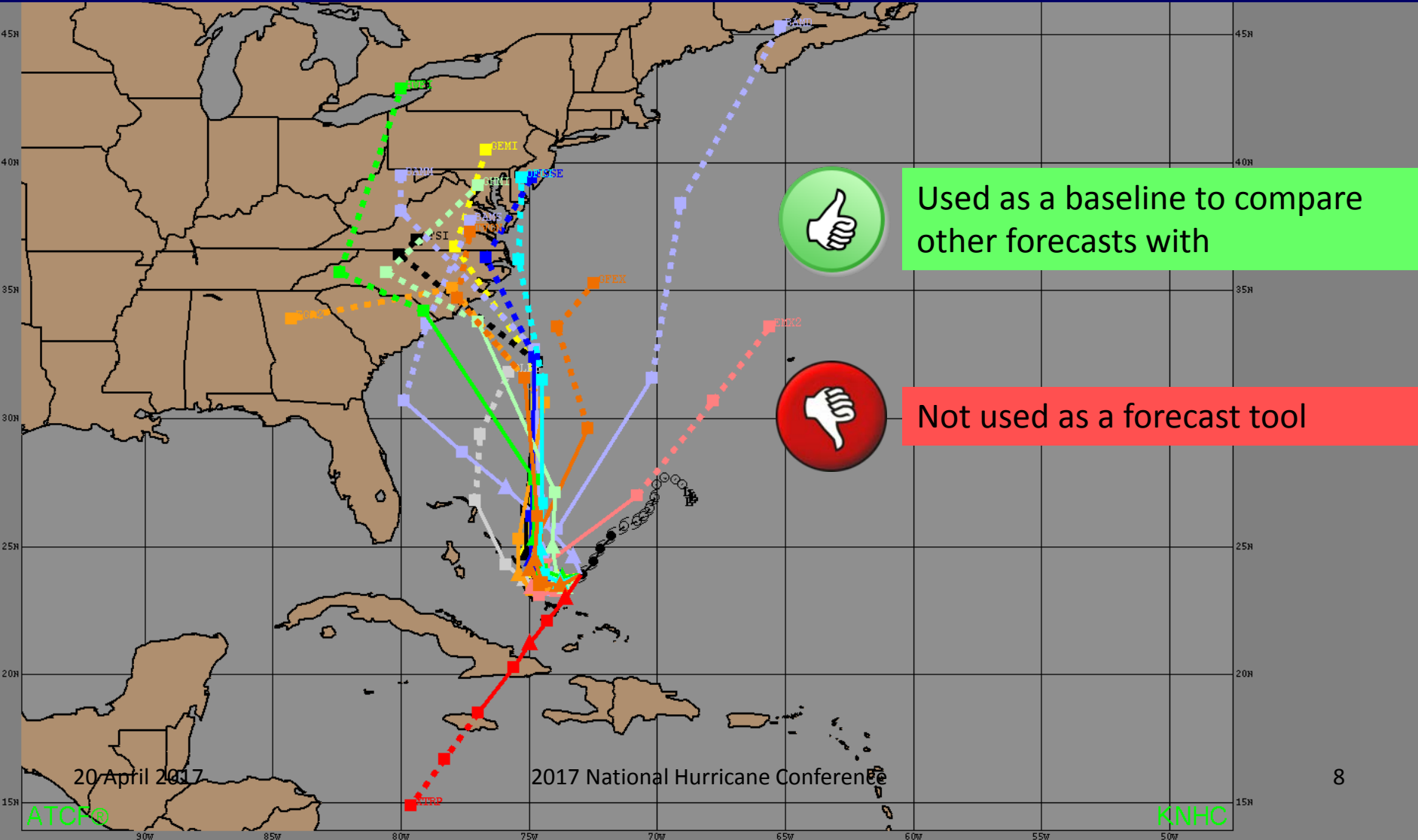- What's missing?

Tropical Cyclone Models
Spaghetti Plots

Tropical Cyclone Models
Extrapolated Motion

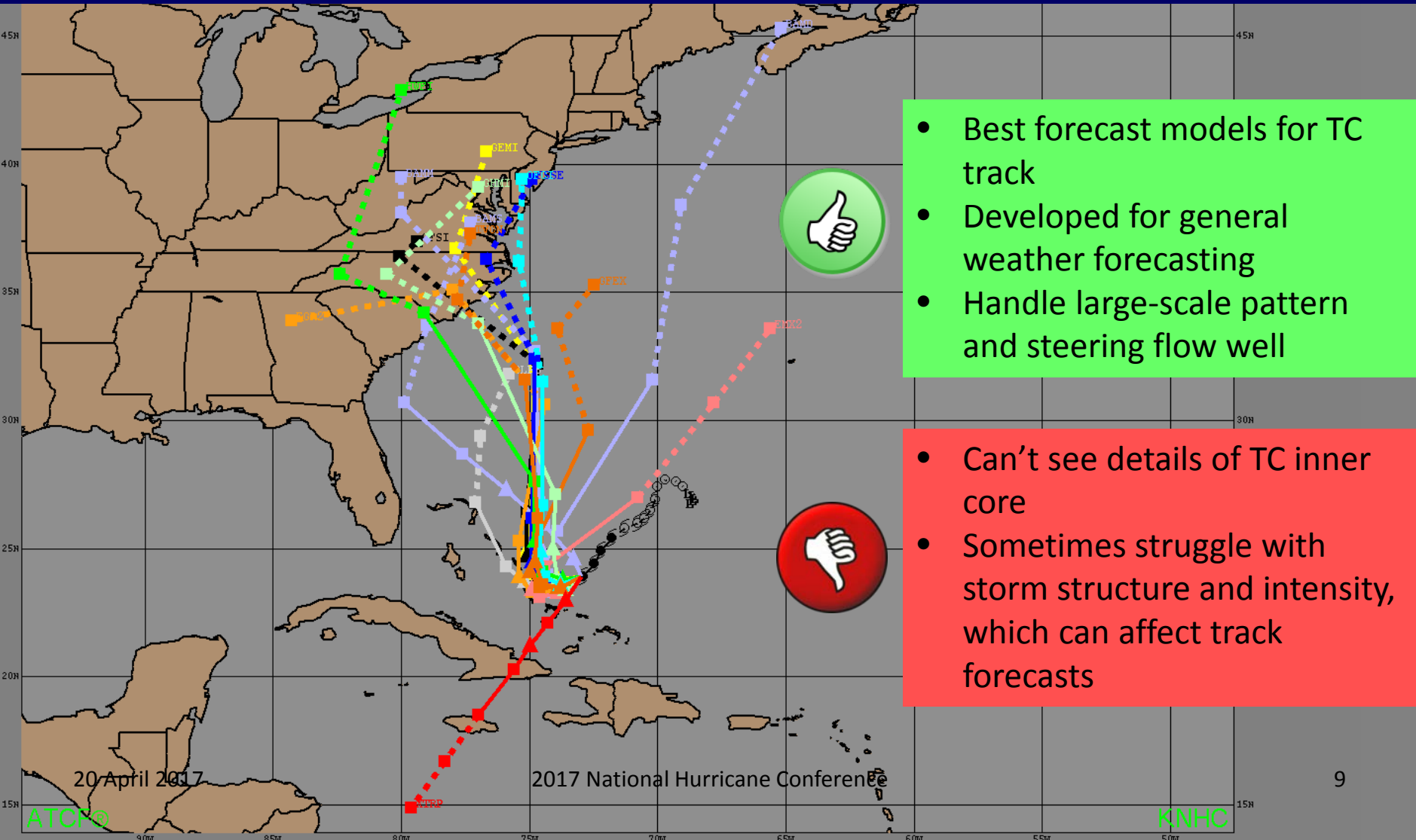Useful if models aren't handling initial motion well in the very short term

No utility beyond 6 or 12 hours at most

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Tropical Cyclone Models
Climatology and Persistence

Used as a baseline to compare other forecasts with

Not used as a forecast tool

Tropical Cyclone Models
Global Models

- Best forecast models for TC track
- Developed for general weather forecasting
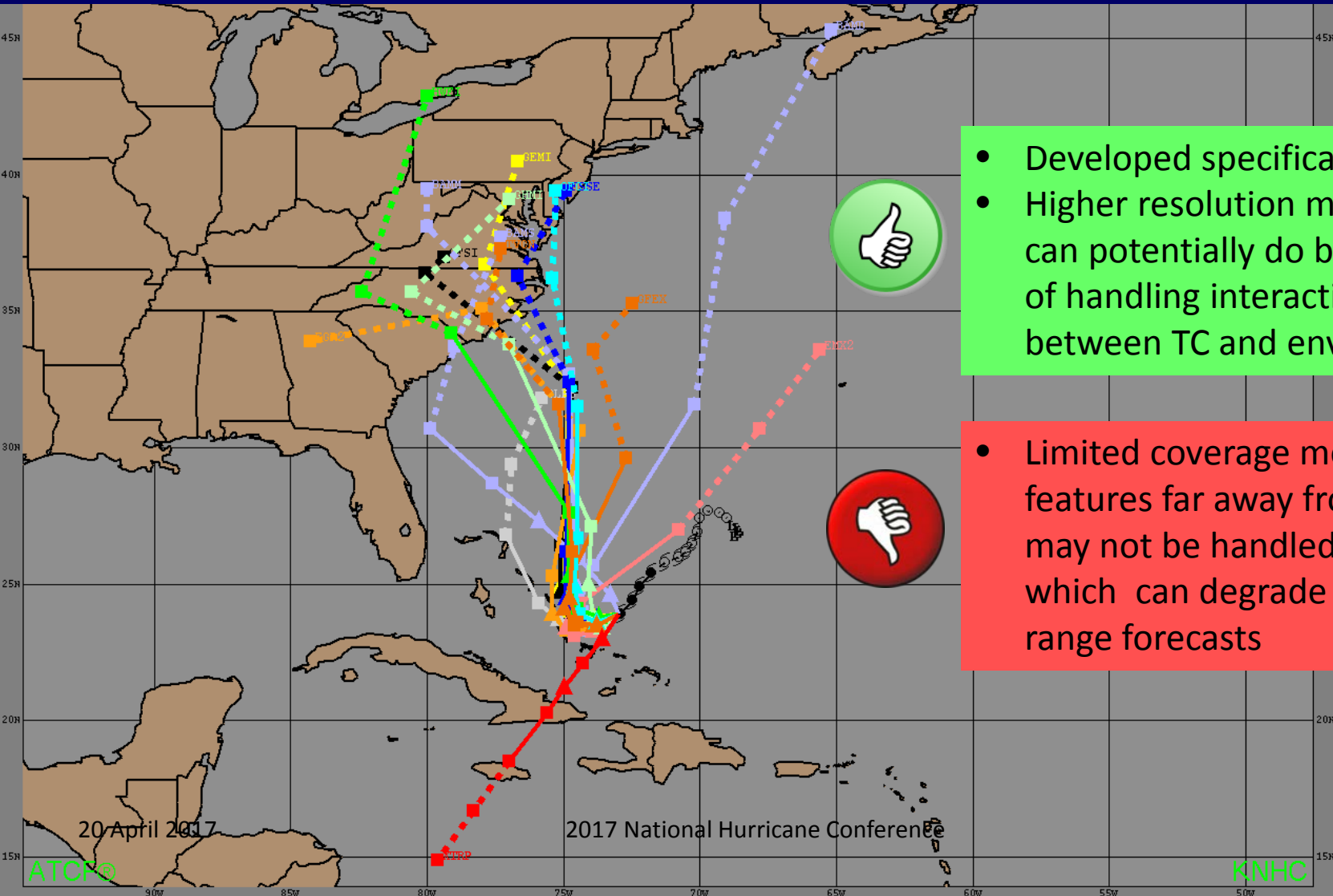- Handle large-scale pattern and steering flow well

- Can't see details of TC inner core
- Sometimes struggle with storm structure and intensity, which can affect track forecasts

Tropical Cyclone Models
Regional Hurricane Models

- Developed specifically for TCs
- Higher resolution means they can potentially do better job of handling interactions between TC and environment
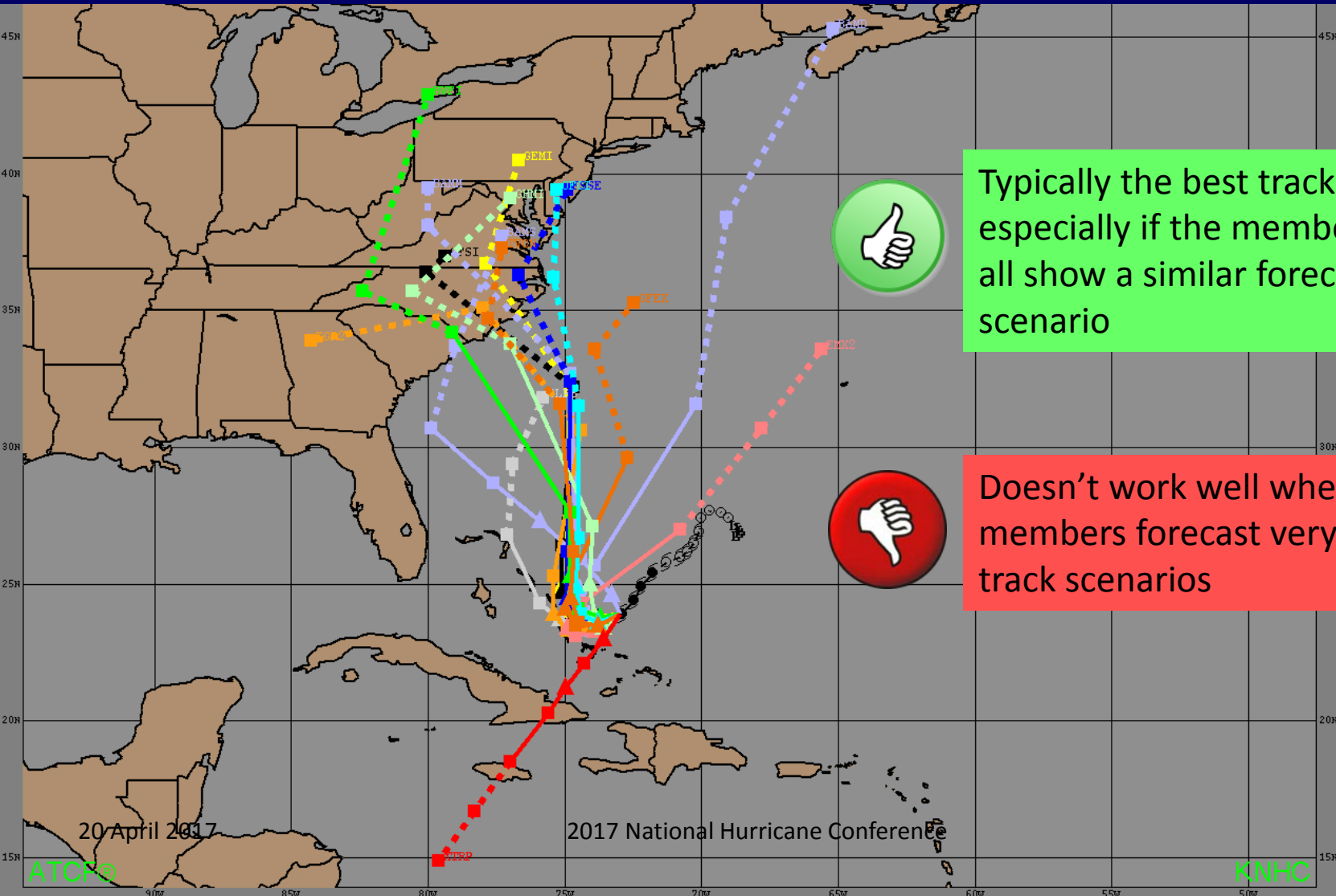
- Limited coverage means features far away from TC may not be handled as well, which can degrade longer-range forecasts

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Tropical Cyclone Models
Consensus Models

Typically the best track guidance, especially if the member models all show a similar forecast scenario

Doesn't work well when members forecast very different track scenarios

Tropical Cyclone Models
Spaghetti Plots – Caution!

- If you're looking at model track plots, you're not seeing the whole picture

  - Some of the best guidance isn't publicly available for proprietary reasons

  - No sense of continuity from cycle to cycle for the various models, trends, etc.

  - Don't have the forecaster's perspective and knowledge to know model strengths and weaknesses, trends, etc.
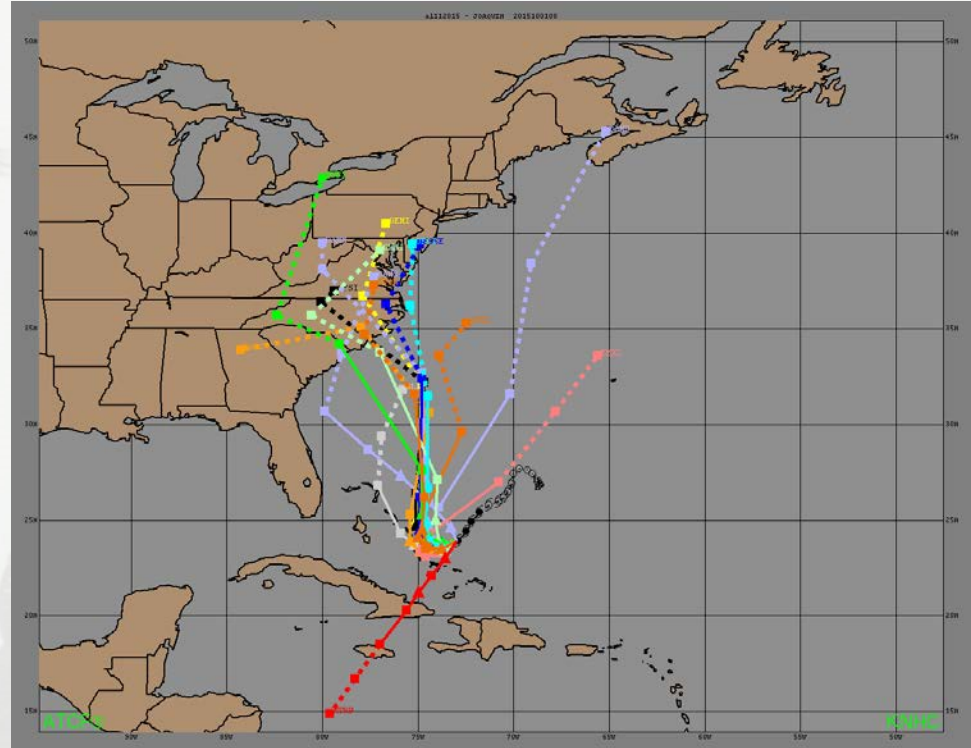
Consensus Models
Examples – Tropical Storm Cristobal (2014)
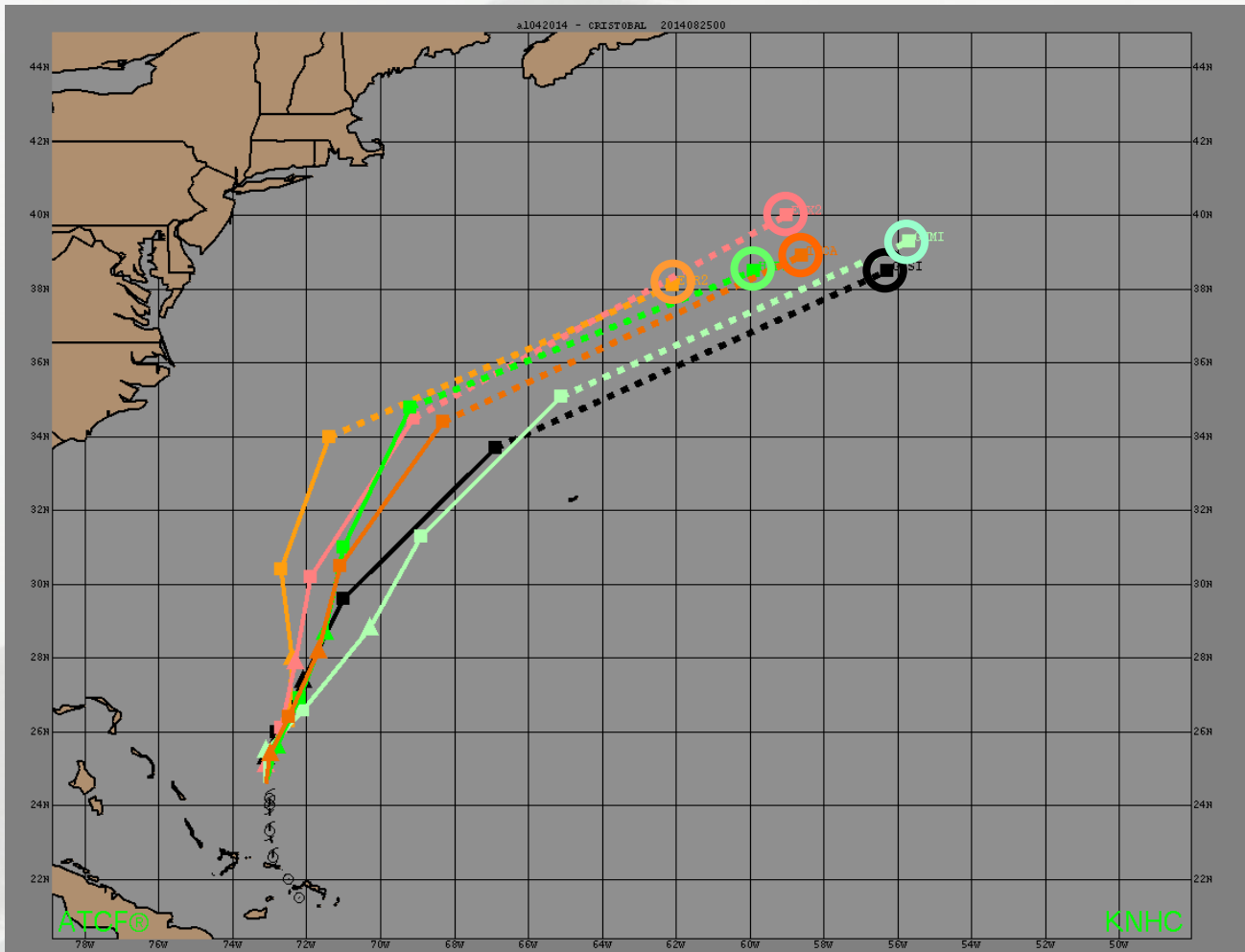
- Model errors are often random (e.g., small variations on a common theme)

- Consensus frequently cancels out these random errors, resulting in a better forecast

Consensus Models
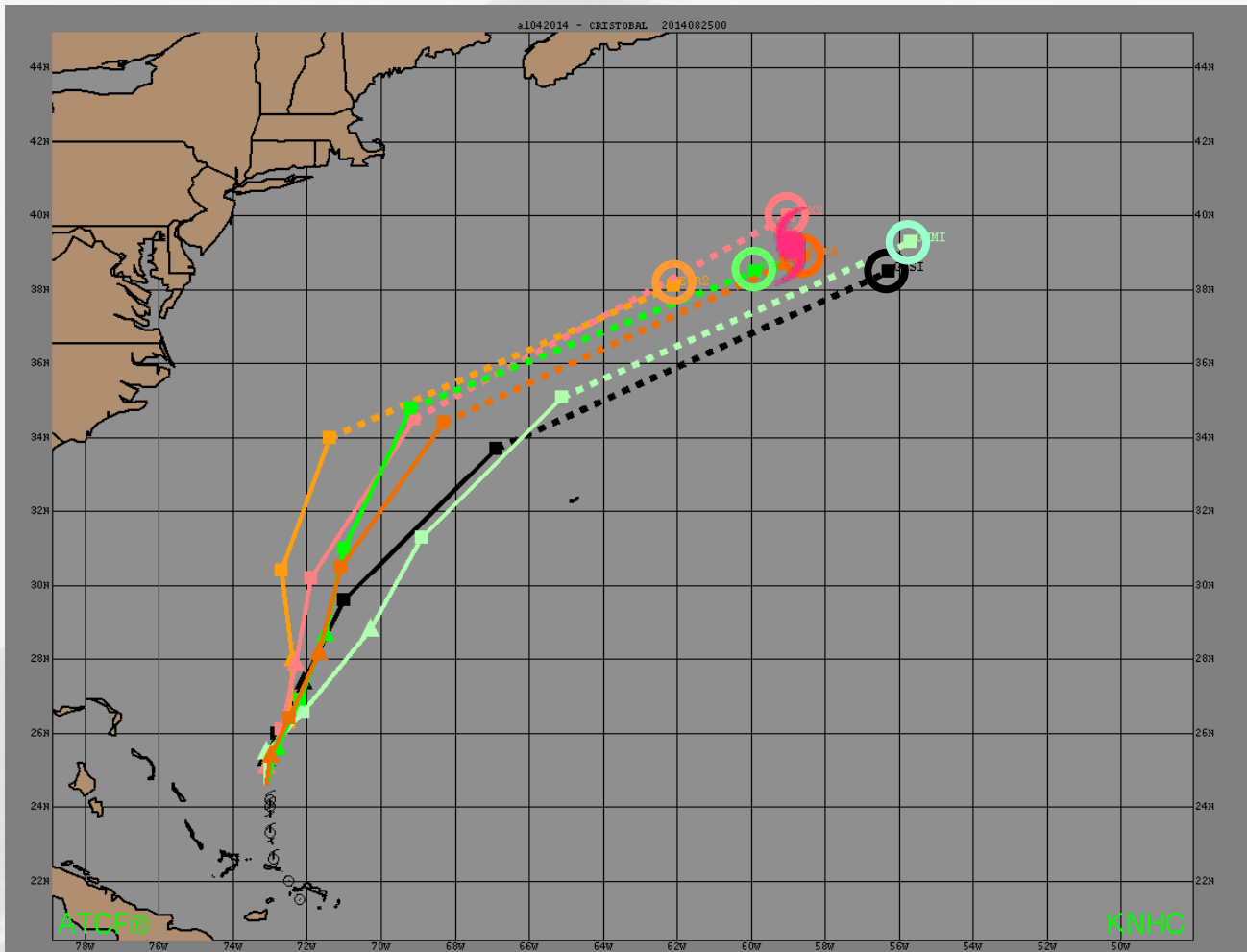## *Examples – Tropical Storm Cristobal (2014)*

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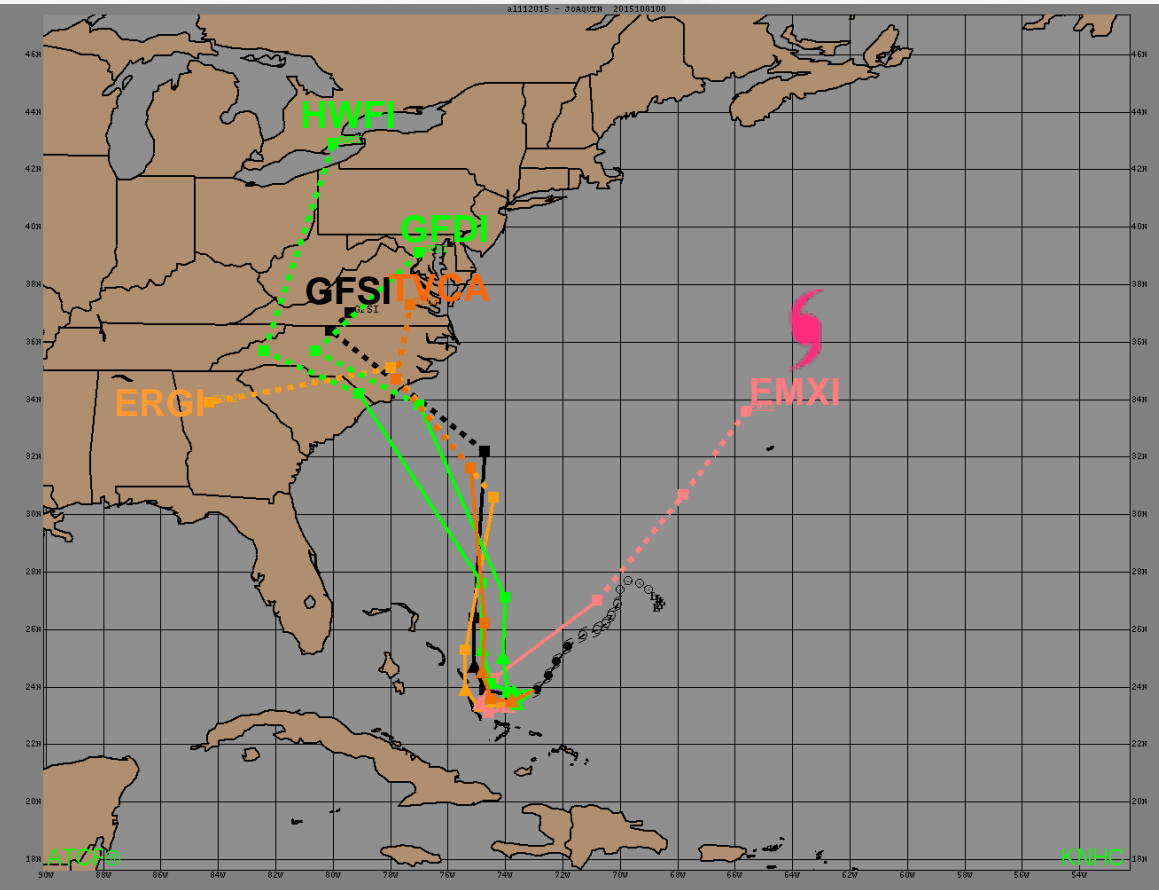
Consensus Models
## *Examples – Hurricane Joaquin (2015)*

- Consensus approach doesn't always work, especially when model scenarios are completely different

- Sometimes the forecaster might want to exclude certain models and form a "selective consensus", if the discrepancies among the models can be resolved
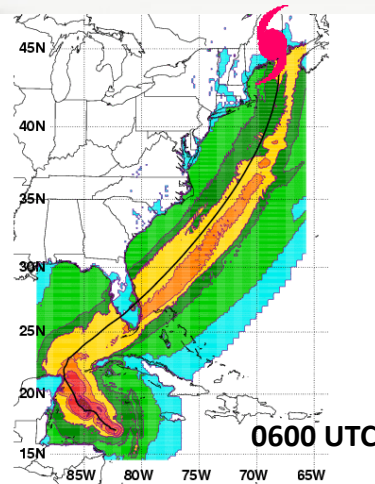
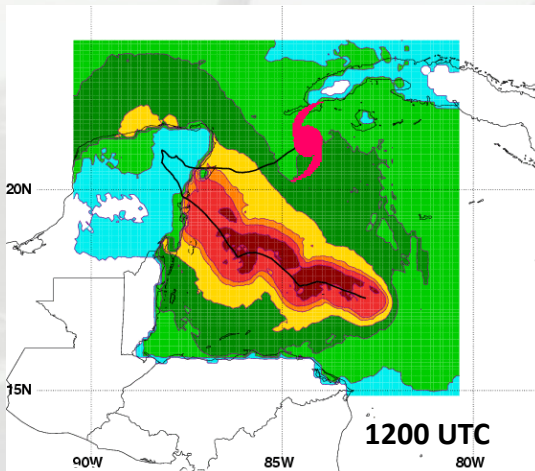- Resolving these discrepancies is very difficult
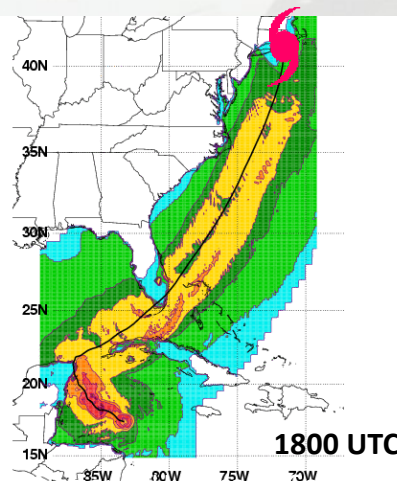
Model Consistency
Hurricane Wilma (2005)
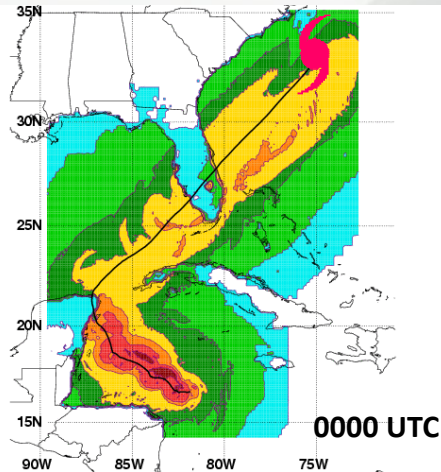
0000 UTC

051019/0000 UTC Maximum Surface Wind Speed (knots) for wilma24l

0600 UTC

051019/0600 UTC Maximum Surface Wind Speed (knots) for wilma24l

1200 UTC

051019/1200 UTC Maximum Surface Wind Speed (knots) for wilma24l

1800 UTC

051019/1800 UTC Maximum Surface Wind Speed (knots) for wilma24l

- Four consecutive runs of the GFDL model for Wilma on 19 October 2005 showed tremendous variability in track and forward speed

- 5-day forecast points ranged from the Caribbean to northern New England over the course of 4 runs

- This suggests very low confidence in the track forecast and that the track is very sensitive to small changes in the analysis or forecast of features in the atmosphere, including the TC itself

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Track Model Trends
Best 48-h Track Model by Storm – 2016

48-h Track Model Forecast Errors by Storm
2016 - Atlantic Basin
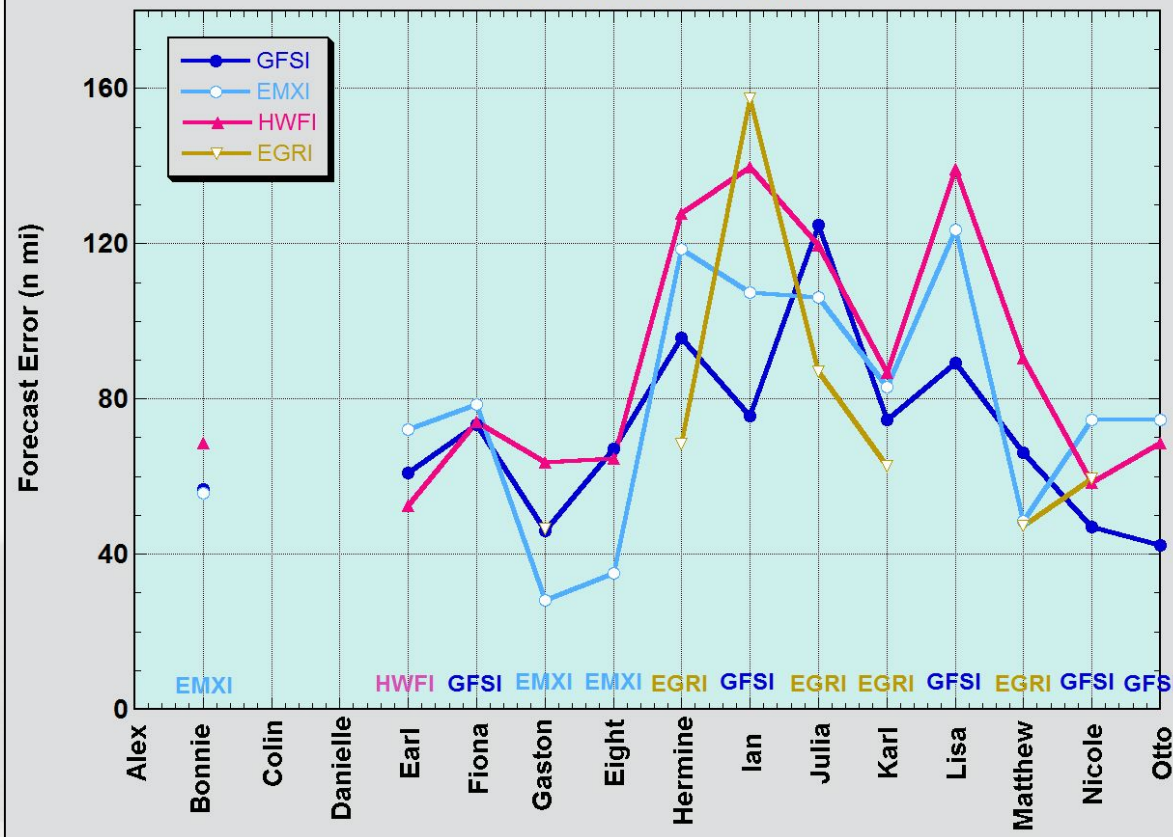
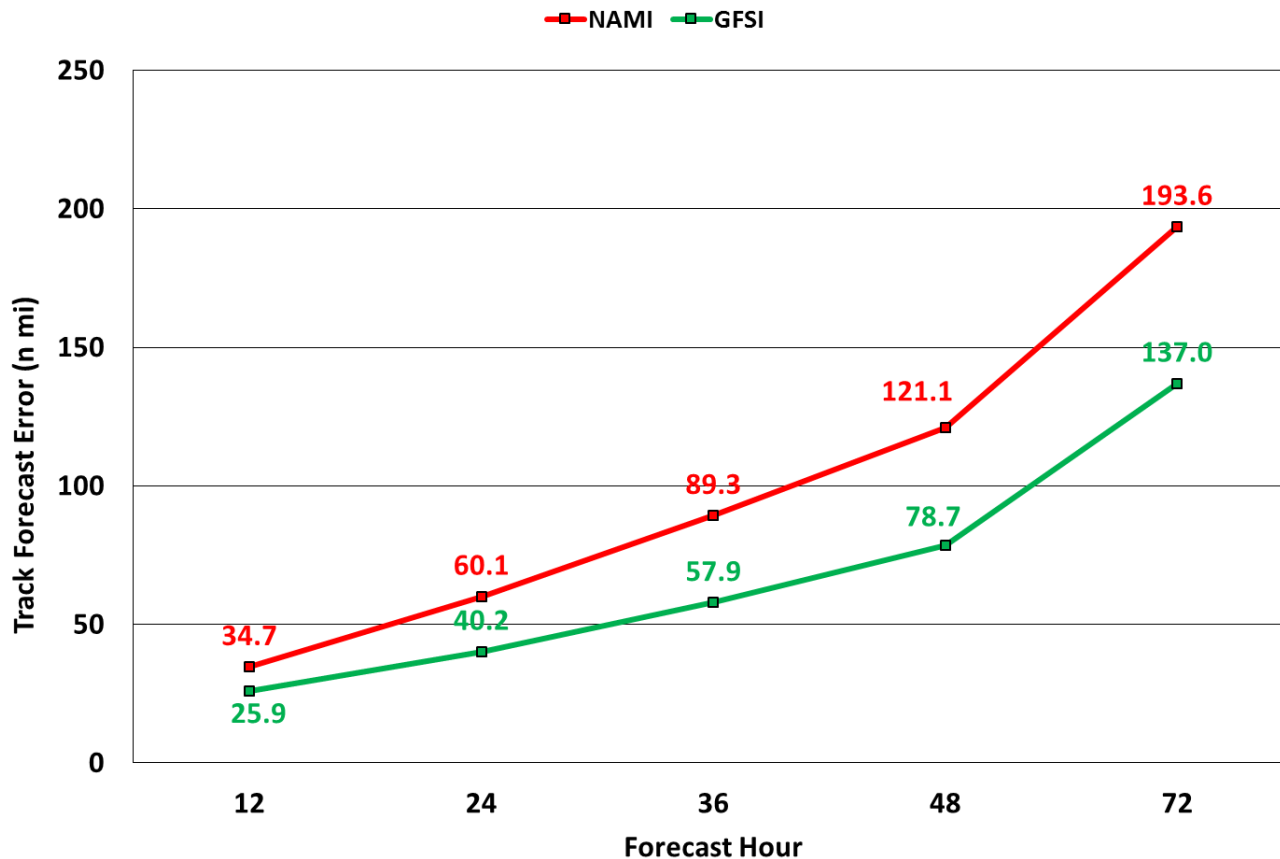Considerable variability from storm to storm, with no clear best model at 48-h across the board

Tropical Cyclone Models
The NAM

2014-2016 GFS and NAM Atlantic Track Error

NAMI GFSI

NAMI values: 34.7, 60.1, 89.3, 121.1, 193.6

GFSI values: 25.9, 40.2, 57.9, 78.7, 137.0

TC track errors from the NAM are about 50% higher than the GFS

The NAM should **not** be used for TC forecasting

Tropical Cyclone Models
Guidance for Invests

- "Invests" are suspect areas that NHC is interested in looking at more closely for a variety of reasons

- Model guidance for invests should be treated with *extreme caution*
  - Guidance for invests can be unreliable and show large swings from one cycle to the next for several reasons:
    - The models may not have a good representation of the invest in the initial analysis (can be too weak, too strong, or in the wrong place)
    - The initial position and motion of invests can be highly uncertain
    - Invests can be relocated many 10s of miles from one cycle to the next as new data become available

- Always refer to the TWO, Potential Tropical Cyclone advisories, and products from your local WFO for information about possible tropical cyclones!
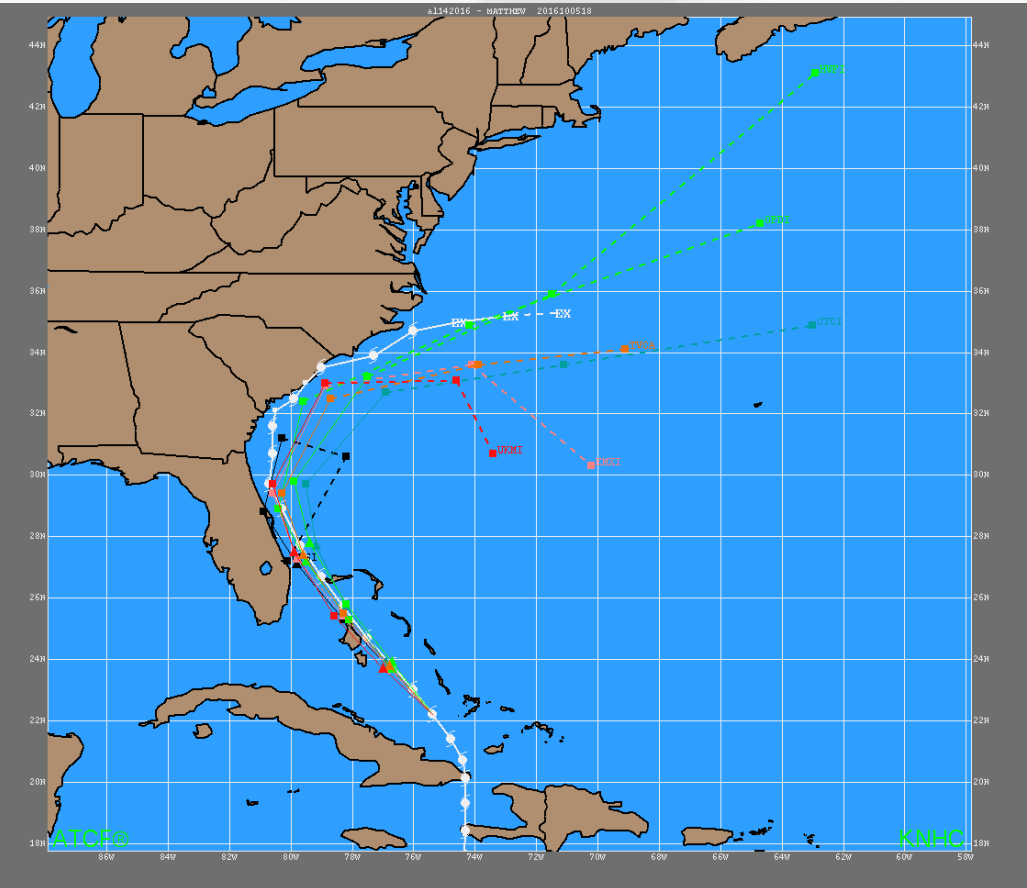
TC Track Forecasting
Forecast Challenges

- Large track forecast errors often result from the following scenarios

  1. Low predictability in the large-scale steering pattern

  2. Misrepresentation of TC structure in models, resulting in improper steering flow

  3. Weak steering currents, resulting in track being driven by mesoscale or convective scale factors
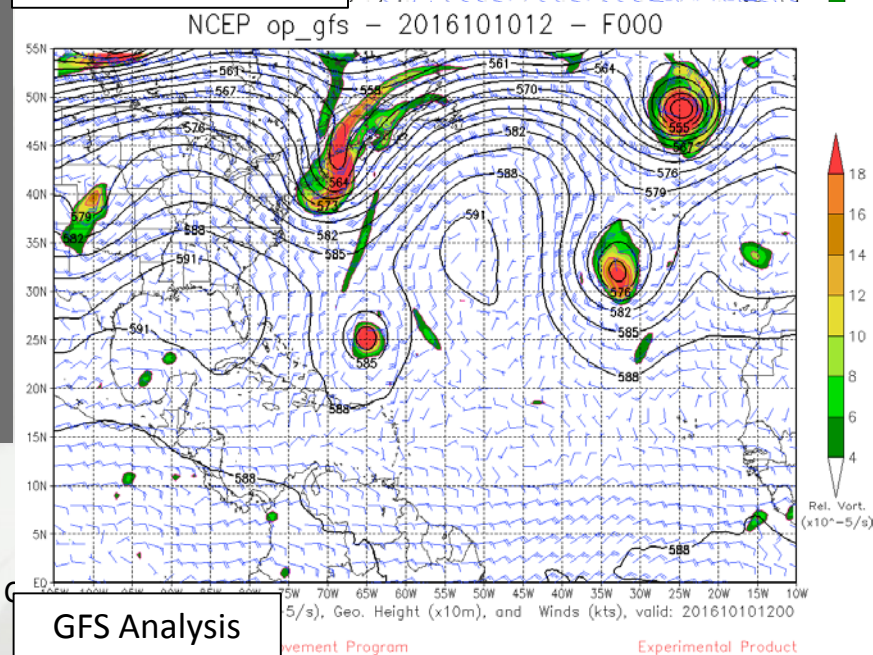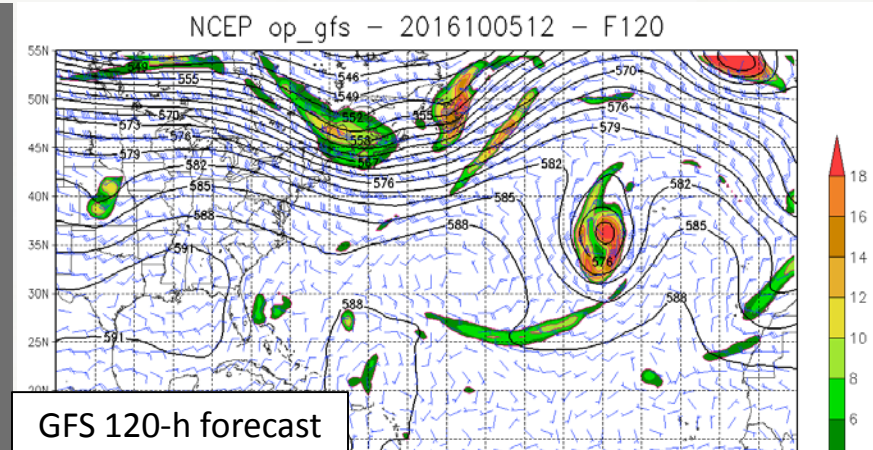
TC Track Forecasting
Forecast Challenges – Low Predictability in Large-Sale Flow

Hurricane Matthew track guidance
18Z 5 Oct. 2016

GFS 120-h forecast

GFS Analysis

20 April 2017

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TC Track Forecasting

Forecast Challenges – Misrepresented TC Structure

- Early in Joaquin's life cycle, it appears the cyclone's track was sensitive to the intensity and structure of the cyclone in the models
- Deep-layer steering flow was similar in both GFS and ECMWF forecasts from 1200 UTC 29 September cycle
    - ECMWF vortex was deeper
    - GFS vortex was shallow and didn't feel deep-layer steering flow
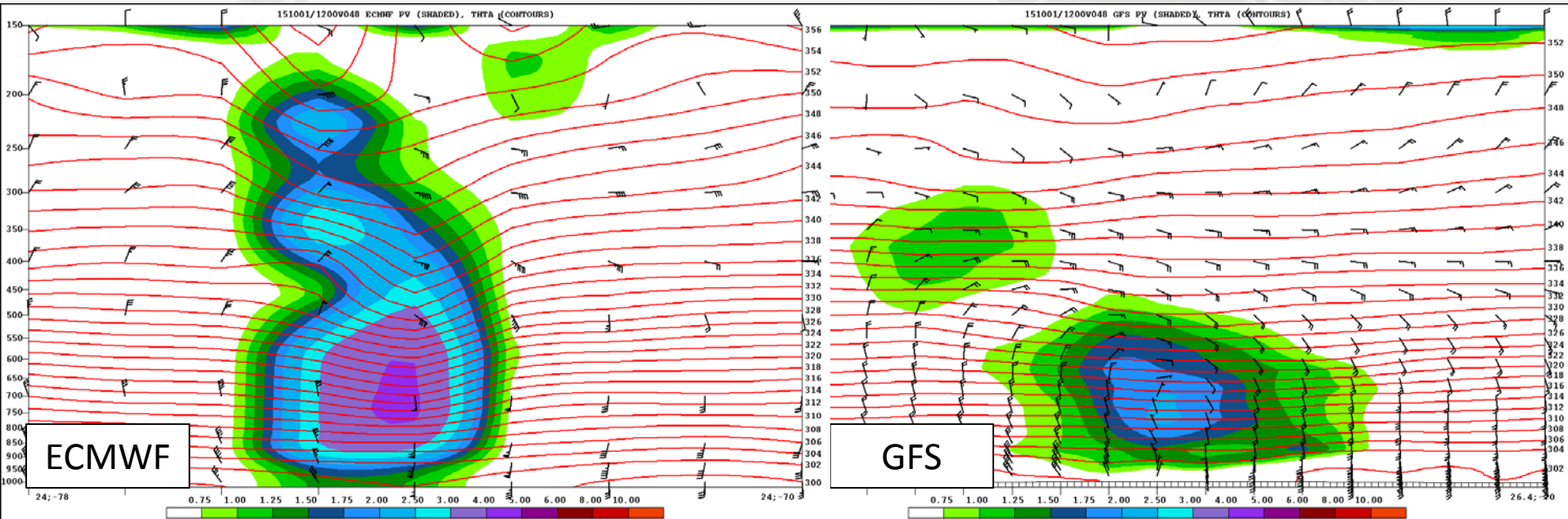
NHC Forecast Philosophy
Forecast Continuity

- Previous official forecast exerts a strong constraint on the current forecast

- Credibility can be damaged by making big changes from one forecast to the next, and then having to go back (flip-flop, windshield-wiper)

  - Changes to the previous forecast are normally made in small increments

  - We strive for continuity within a given forecast (e.g., gradual changes in direction or speed from 12 to 24 to 36 h, etc.)

- As a result, NHC official forecasts are often slower to reflect big changes than the model guidance

Forecast Continuity
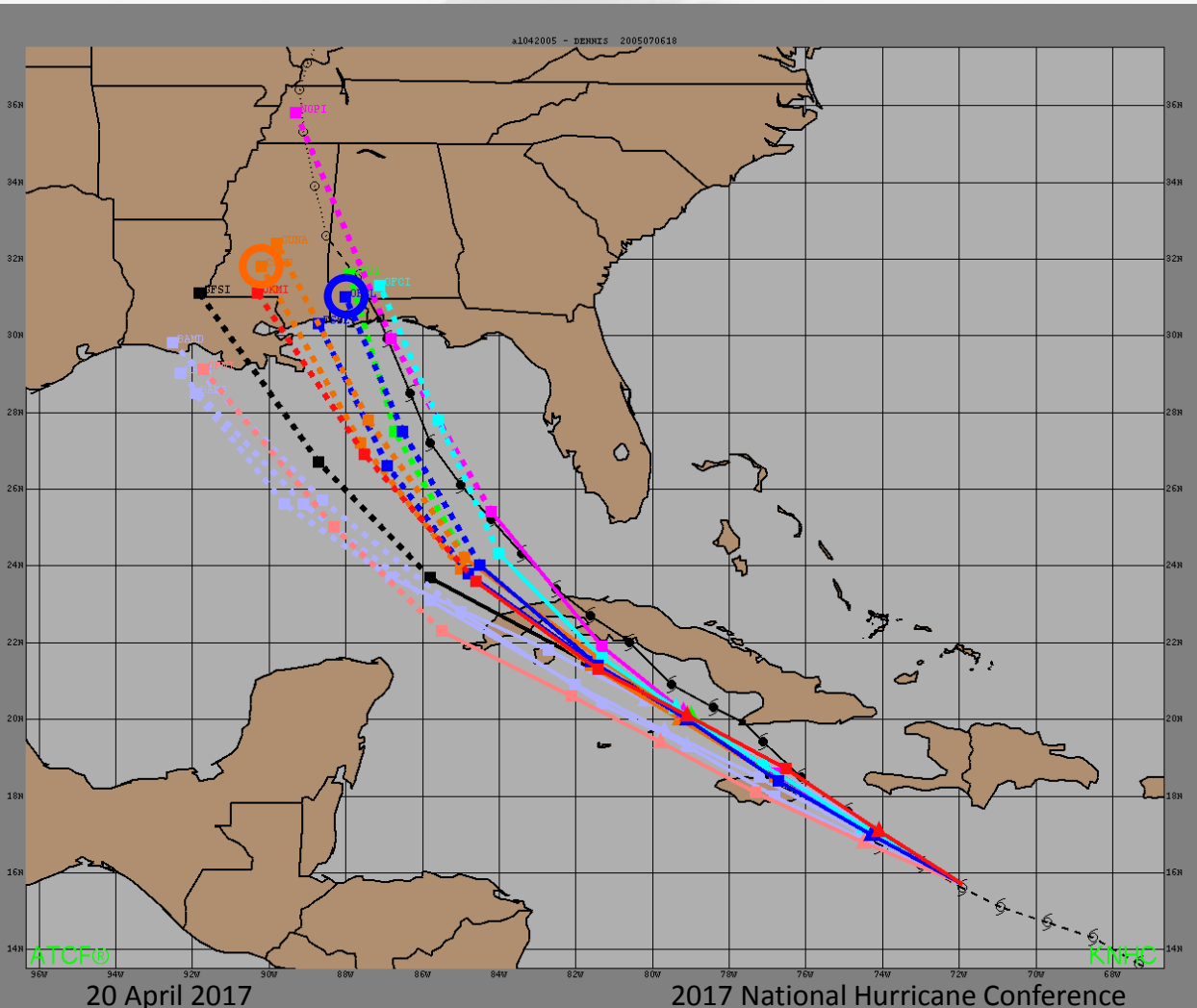## *Hurricane Dennis – 12Z 6 July 2005*
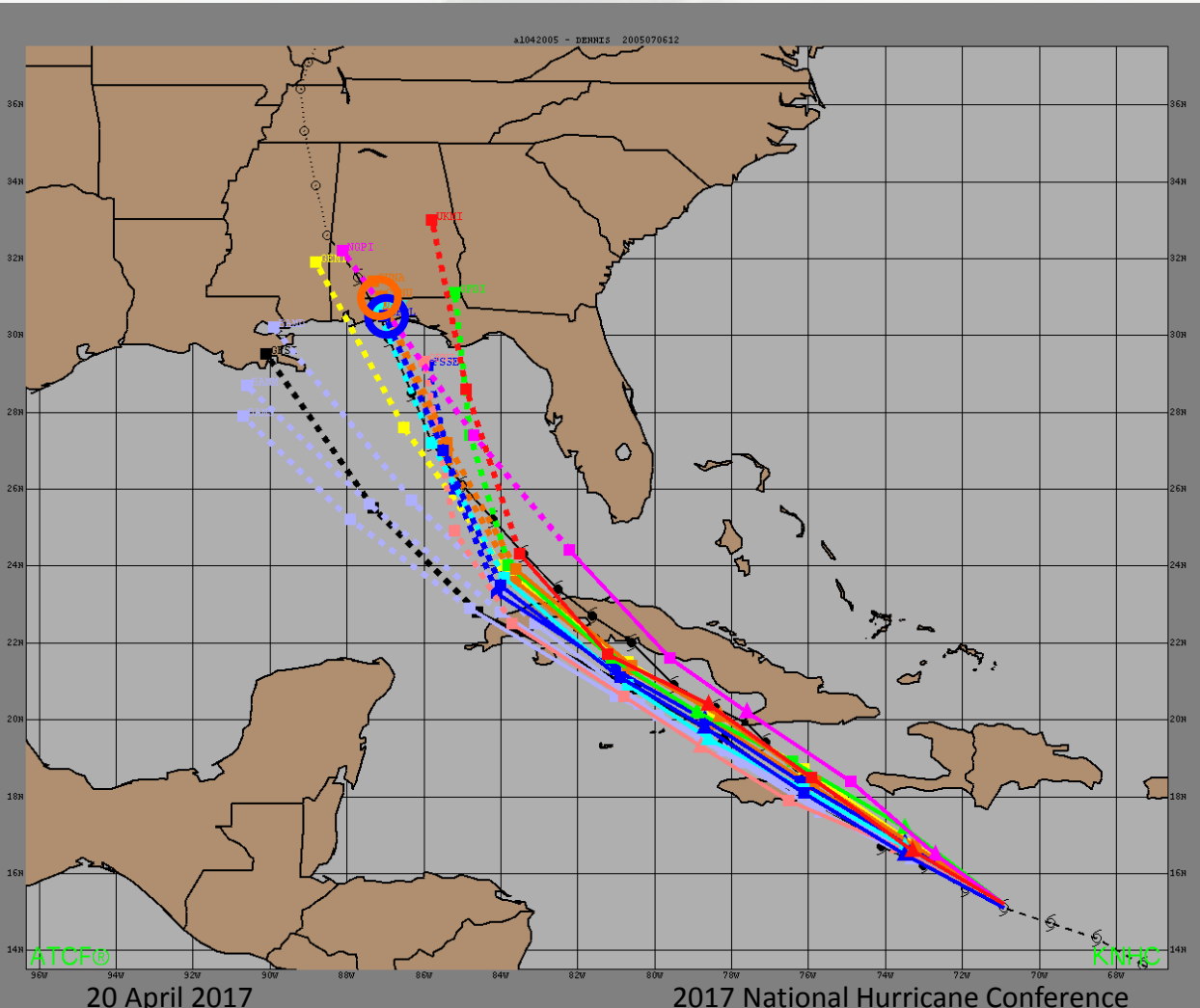
Official forecast near model consensus in western Florida panhandle

◯ **Official Forecast**

◯ **Consensus**

Forecast Continuity
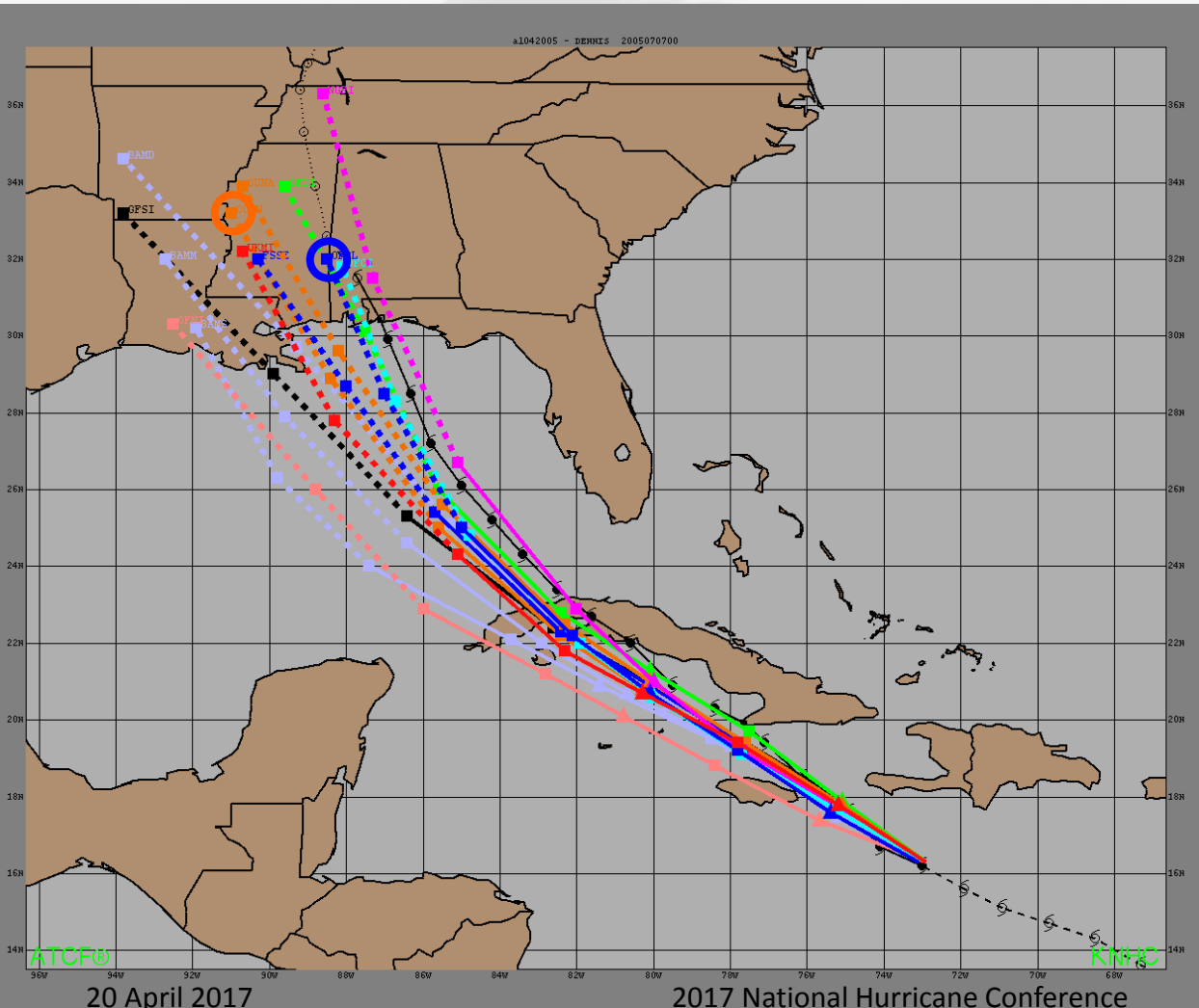## *Hurricane Dennis – 18Z 6 July 2005*

Guidance shifts sharply westward

Official forecast nudged westward into Alabama

⭘ **Official Forecast**

⭘ **Consensus**

Forecast Continuity
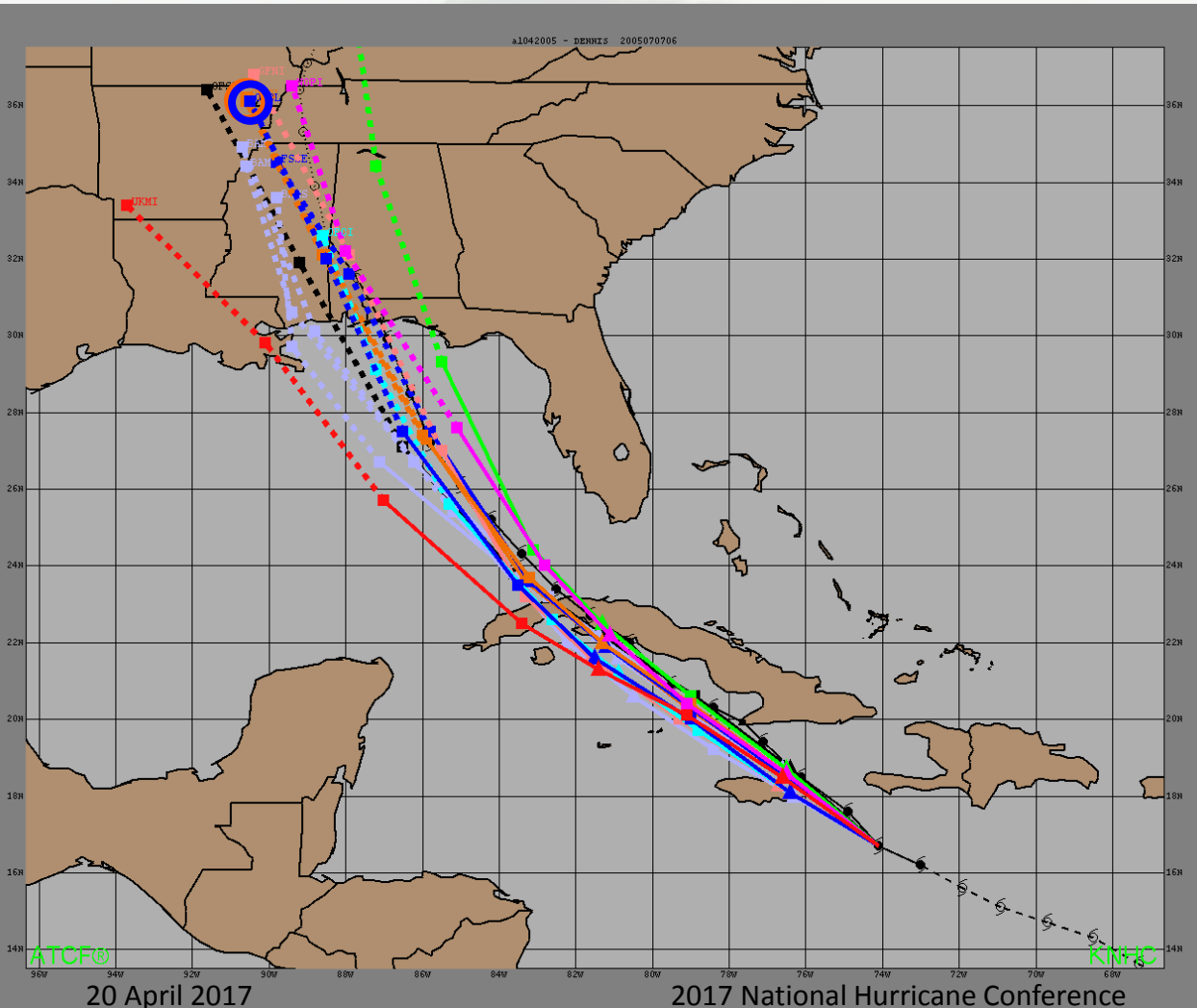## *Hurricane Dennis – 00Z 7 July 2005*

Little overall change to guidance, but NOGAPS shifts slightly eastward

Little change in official forecast

◯ **Official Forecast**
◯ **Consensus**

Forecast Continuity
Hurricane Dennis – 06Z 7 July 2005

a1042005 – DENNIS 2005070706

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Rest of the guidance shifts eastward

Official forecast is now near the center of the guidance and close to the actual track

○ **Official Forecast**
○ **Consensus**

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TC Track Models
Concluding Remarks

- Global models are the most skillful for TC track prediction

- Consensus aids are more skillful than most individual models, and often beat the official track forecast

    - NHC forecasters have philosophical constraints on the official forecast that leads to a certain amount of response lag

    - May contribute to forecast biases and slightly poorer performance than the consensus

- While it is possible to beat the models from time to time, model performance has improved significantly over the years, and they are very difficult to beat consistently

TC Track Models
Concluding Remarks

- Large track forecast errors often occur due to
  - Uncertainty in large-scale atmospheric flow
  - Uncertainty in TC intensity and structure
- Track guidance for invests should be treated with extreme caution

TC Track Models

Thank You